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FPCAS3D User's Guide: A Three Dimensional Full Potential Aeroelastic Program

Version 1.0

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FPCAS3D User's Guide: A Three Dimensional Full Potential Aeroelastic Program

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Abstract

The FPCAS3D computer code has been developed for aeroelastic stability analysis of bladed disks such as those in fans, compressors, turbines, propellers, or propfans. The aerodynamic analysis used in this code is based on the unsteady three-dimensional full potential equation which is solved for a blade row. The structural analysis is based on a finite-element model for each blade. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis are not given in this report. This guide can be used to assist in the preparation of the input data required by the FPCAS3D code. A complete description of the input data is provided in this report. In addition, six examples, including inputs and outputs, are provided.

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1. INTRODUCTION

This is a user's guide for the FPCAS3D computer code which was developed for aeroelastic stability analysis of bladed disks such as those found in compressors, turbines, propellers, or propfans. This guide will help the user in the preparation of the input data files required by the FPCAS3D code. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis will not be given in this guide. Instead, the reader is directed to specific references that deal with each of these items. The FPCAS3D code was developed at the Structural Dynamics Branch at NASA Lewis Research Center. It is made available strictly as a research tool. Neither NASA Lewis Research Center, nor any individuals who have contributed to the development of the code, assume any liability resulting from the use of this code beyond research needs.

The aerodynamic analysis used in this code is based on the unsteady three-dimensional full potential equation. This equation is solved for a complete blade row or for a specified number of blade passages in a blade row. The structural analysis is based on a finite element model for each blade. Either a frequency domain or a time domain flutter analysis is possible.

2. ANALYSIS

Detailed descriptions of the aerodynamic and aeroelastic analyses can be found in Refs. 1 and 2. These references contain a full description of the full potential formulation including the governing equations and boundary conditions. The transformation of the equations to the computational plane and the subsequent discretization and solution of these equations is also described in detail. A finite volume approach is used to solve the full potential equation and a Newton-iteration method is used to solve the non-linear problem as a series of linear problems. Refs. 3 and 4, describe the extension of the analysis to arbitrary interblade phase angles. In Ref. 5, the combined pulse response and influence coefficient method is detailed.

3. DESCRIPTION OF CODE

The FPCAS3D code is written in FORTRAN. It was developed and is operational on the Cray YMP computer at NASA Lewis Research Center under the UNICOS operating system. It is also operational on the NAS Cray C-90 computer at NASA Ames Research Center under the UNICOS operating system. There are six different versions of the FPCAS3D code, as described in the following table.

Although the six versions have a lot of common code, each version has some unique features. A trade-off between the in-core storage requirement and the computational time requirement is possible for cases involving large number of blades (blade passages). For example, if large amount of in-core storage is available, then versions 2 and 5 would be preferred over versions 1 and 4 since these require lower amount of computational time.

Features of the six versions of FPCAS3D

Version	Flutter Method	Feature(s)
1	freq. domain	In-core storage requirement is reduced by swapping data to disk files.
2	freq. domain	All data storage is in-core, leading to large in-core storage requirements.
3	freq. domain	All data storage is in-core; one blade passage is used for in-phase blade motion calculations.
4	time domain	In-core storage requirement is reduced by swapping data to disk files.
5	time domain	All data storage is in-core, leading to large in-core storage requirements.
6	time domain	All data storage is in-core; one blade passage is used for in-phase blade motion calculations.

4. DESCRIPTION OF INPUT DATA

In addition to the selected version of the source code `fpcas3d.f`, three parameter definition files `para1.f`, `para2.f`, and `para3.f` are required. These are used to specify the problem-dependent array dimensions. Input data, modal structural data, and blade shape data required by the code are provided in the files `fpcas3d.input`, `fpcas3d.mode.input`, and `fpcas3d.blade.input`, respectively.

4.1 Parameter Definition Files: para1.f, para2.f, and para3.f

These files contain parameter definitions that are dependent on the size of the problem. These parameters are used to specify dimensions of arrays used within the code. The use of the parameter definition files eliminates the need to edit the source code for the purpose of changing array dimensions. The contents of the parameter definition files are transferred to the source code (at the time of compilation) by `INCLUDE` statements in the code. Each line in these files cannot be more than 72 characters in length. Each parameter definition file contains a single `PARAMETER` statement.

In file `para1.f`, three parameters `IMX`, `JMX`, and `KMX` are listed in the form shown below. These three parameters specify the maximum number of grid points in the streamwise, circumferential, and spanwise directions in each blade passage. The actual number of grid points used in a problem must be less than or equal to these maximum limits.

```
PARAMETER ( IMX=56, JMX=11, KMX=24 )
```

In file `para2.f`, three parameters `NXPM`, `NRPM`, and `NNODM` are listed in the form shown below. `NXPM` and `NRPM` specify the maximum number of grid points on the blade surface in the chordwise and spanwise directions. `NNODM` is the maximum number of all finite element grid points.

```
PARAMETER ( NXPM=21, NRPM=21, NNODM=500 )
```

In file `para3.f`, the maximum number of blade passages (or blades) `NPS` is specified as shown below. The file `para3.f` is required only with versions 2, 4, and 5.

```
PARAMETER ( NPS=2 )
```

4.2 Input Data File: `fpcas3d.input`

This file contains the standard (unit 5) input that the `FPCAS3D` code requires. All input is read in free format using `'READ (5,*)'` FORTRAN statements. Typically, each `READ` statement is used to read the values of many input variables. In such cases, the input values are separated by one or more blank spaces. If all the input values do not fit on a single line, they can be placed on several additional lines. No continuation character is required, but individual values cannot be split across lines. In the input file, the values of each set of input variables is preceded by a line containing the names of the variables. The code does not read these names of variables and these are included in the input

data file only to help the user in identifying the variables whose values are present on the subsequent line or lines. Since the contents of these lines are ignored by the code, the user can use these lines to annotate the input file to a limited extent.

The input variables are described below in the order in which they are required in the input data file. Note that some input variables are required only in specific versions of FPCAS3D; the versions for which a particular variable is required are listed after the description.

variable: TITLE
 type: character variable of length 80
 description: job title
 versions: all

variable: IEXTR
 type: integer variable
 description: flowfield extrapolation scheme flag:
 IEXTR=1 initial guess extrapolated linearly from previous two
 time levels
 IEXTR=0 flowfield at previous time level used as initial guess
 versions: all

variable: INUM
 type: integer variable
 description: number of Newton sub-iterations to be performed at each time
 level
 versions: all

variable: INI
 type: integer variable
 description: initial flowfield flag:
 INI=0 assume initial flowfield to be uniform; generally used
 with NSTDY=0 to obtain a steady flowfield
 INI=1 read initial flowfield from restart files from unit 8;
 a restart file is written to unit 8 at the end of a steady
 run (NSTDY=0)
 versions: all

variable: MINF
 type: real variable
 description: Mach number of flow at inlet

versions: all

variable: ADV
type: real variable
description: advance ratio
versions: all

variable: BET3Q
type: real variable
description: blade setting angle at three-quarter span location (degrees)
versions: all

variable: SOMGA
type: real variable
description: in versions 1, 2, and 3,
for NSTDY=0, it is not used
for NSTDY=1, it is the vibration frequency of the blade
non-dimensionalized by reference speed of sound
and tip diameter of the blade
for NSTDY=2, it is the duration of the pulse motion of the blade
non-dimensionalized by reference speed of sound
and tip diameter of the blade

in versions 4, 5, and 6,
for NSTDY=0, it is not used
for NSTDY=2, it is used to specify initial velocity of the blades
in conjunction with VEL5 (NBLADE) and FACTOR; refer
to the source code of subroutine ELAS for details
versions: all; different meaning in versions 1-3 and 4-6

variable: NTMX
type: integer variable
description: total number of time steps
versions: all

variable: DTAU
type: real variable
description: time step non-dimensionalized by reference speed of sound and
tip diameter of the blade
versions: all

variable: NBS

type: integer variable
description: number of blades (or blade passages)
versions: all, except versions 3 and 6, which are restricted to one blade (blade passage) or NBS=1

variable: NSTDY
type: integer variable
description: flag to indicate type of motion:
 NSTDY=0 for no elastic motion (rigid blades)
 NSTDY=1 for harmonic vibration (versions 1, 2, and 3)
 NSTDY=2 for pulse motion (versions 1, 2, and 3)
 NSTDY=2 for aeroelastic vibration motion (versions 4, 5, and 6)
versions: all

variable: FACTOR
type: real variable
description: scaling factor used to scale down the mode shape functions to prevent very large displacement of blades
versions: all

variable: (IMOV(NBLADE), NBLADE = 1, NBS)
type: array of integer variables
description: blade motion flags:
 IMOV(NBLADE)=0 for blade to be held rigid
 IMOV(NBLADE)=1 for blade to be vibrated
versions: versions 1 and 2 only

variable: MOVEMODE
type: integer variable
description: index of mode to be used for blade vibration
versions: versions 1-3 only

variable: RHUB0
type: real variable
description: radius of hub as a fraction of tip diameter of blade
versions: all

variable: NMODE
type: integer variable
description: number of modes in aeroelastic calculation
versions: versions 4-6 only

variable: P0
 type: real variable
 description: reference pressure (psi)
 versions: versions 4-6 only

variable: A0
 type: real variable
 description: reference speed of sound (inch/sec)
 versions: versions 4-6 only

variable: (OM(IM), IM = 1, NMODE)
 type: array of real variables
 description: natural frequency of vibration (Hz) for each mode
 versions: versions 4-6 only

variable: (GM(IM), IM = 1, NMODE)
 type: array of real variables
 description: generalized mass for each mode
 versions: versions 4-6 only

variable: (VEL(NBLADE), NBLADE= 1, NBS)
 type: array of real variables
 description: used to specify initial velocity of each blade in conjunction with SOMGA and FACTOR; refer to the source code of subroutine ELAS for details
 versions: versions 4-6 only

variable: IAIRFL
 type: integer variable
 description: flag for blade shape:
 IAIRFL=0 to use the same chordwise thickness distribution at all spanwise locations on the blade; this thickness distribution is specified by CHD16(I) and the maximum thickness distribution in the spanwise direction is specified by TMAX(J)
 IAIRFL=1 to use a thickness distribution array TMPTTBL(I,J)
 versions: all

variable: (TMAX(J), J = 1, 15)
 type: array of real variable
 description: spanwise maximum thickness distribution for IAIRFL=0, non-dimensionalized by local chord length

versions: all

variable: (CHD16(I), I = 1, 15)
type: array of real variable
description: chordwise thickness distribution for IAIRFL=0,
non-dimensionalized by two times the maximum thickness
versions: all

variable: ((TMPTTBL(I,J), I = 1, 15), J = 1, 15)
type: array of real variable
description: thickness distribution for IAIRFL=1,
non-dimensionalized by local chord length
versions: all

4.3 Blade Shape Data File: fpcas3d.blade.input

This file contains the input required by the grid (mesh) generator. All versions of the FPCAS3D code require this blade shape data file and all the input values in it. Note that this file contains values for some input variables which have only one meaningful value. For example, the number of blade rows (NBLROW) must be one since the FPCAS3D code does not model more than one blade row. For such variables, values other than those specified in the description will lead to meaningless results. These variables are retained only to provide compatibility of input with other codes that utilize the same grid generator. All input values are read in free format from unit 4. The input variables are described below in the order in which they are required in the input file. The blade tip radius is used to non-dimensionalize all variables with length dimensions.

variable: IGEOM
type: integer variable
description: **must** be set to IGEOM=2

variable: NBLROW
type: integer variable
description: **must** be set to NBLROW=1

variable: ITHETA
type: integer variable

description: **must** be set to ITHETA=1

variable: NINPTS

type: integer variable

description: number of points in the inlet section; the inlet section consists of a region of the grid near the inlet boundary where the axial grid spacing is uniform; NINPTS=0 is recommended

variable: NEXPTS

type: integer variable

description: number of points in the exit section; the exit section consists of a region of the grid near the exit boundary where the axial grid spacing is uniform; NEXPTS=0 is recommended

variable: NBLPTZ

type: integer variable

description: number of points on the blade surface in the chordwise direction

variable: NBLPTR

type: integer variable

description: number of points on the blade surface in the spanwise direction

variable: NBLPTT

type: integer variable

description: number of points on the blade surface in the circumferential direction

variable: ZINLET

type: real variable

description: axial location of inlet boundary

variable: ZEXIT

type: real variable

description: axial location of exit boundary

variable: RATIN

type: real variable

description: ratio of axial spacing between adjacent grid lines from blade leading edge to the inlet boundary

variable: RATEX
type: real variable
description: ratio of axial spacing between adjacent grid lines from blade trailing edge to the exit boundary

variable: RATBB
type: real variable
description: **must** be set to RATBB=1.0

variable: RATBLZ
type: real variable
description: ratio of axial spacing between adjacent grid lines on blade surface

variable: RATBLR
type: real variable
description: ratio of radial spacing between adjacent grid lines on blade surface

variable: RATBLT
type: real variable
description: ratio of circumferential spacing between adjacent grid lines on blade surface

variable: RATTIP
type: real variable
description: ratio of radial spacing between adjacent grid lines from blade tip to outer boundary

variable: NHUB
type: integer variable
description: number of points used to specify the shape of the hub

variable: NTIP
type: integer variable
description: number of points used to specify the shape of the outer boundary

variable: (ZHUB(I), I = 1, NHUB)
type: array of real variables
description: axial locations of points used to specify the shape of the hub

variable: (RHUB(I), I = 1, NHUB)
type: array of real variables
description: radial locations of points used to specify the shape of the hub

variable: (ZTIP(I), I = 1, NHUB)
type: array of real variables
description: axial locations of points used to specify the shape of the outer boundary

variable: (RTIP(I), I = 1, NHUB)
type: array of real variables
description: radial locations of points used to specify the shape of the outer boundary

variable: NBLD
type: integer variable
description: number of blades in the blade row

variable: NBLPL
type: integer variable
description: **must** be NBLPL=15

variable: NPPP
type: integer variable
description: **must** be NPPP=15

4.4 Blade Modal Structural Data File: fpcas3d.mode.input

This file contains the modal structural input data. All versions of the FPCAS3D code require this input file. This file includes the finite element grid point coordinates and the mode shape functions. Note that all this data is required even for steady calculations, although the mode shape functions are not actually used in the calculations. All input values are read in free format from unit 3. The input variables are described below in the order in which they are required in the input file.

variable: NNODE
type: integer variable

description: number of grid points (nodes) in the finite element model

variable: BET3Q0

type: real variable

description: blade setting angle at three-quarter span location (degrees) for the finite element model; if this differs from the value of BET3Q0 specified in fpcas3d.input, the finite element grid and mode shape functions will be rotated by the difference.

variable: (GRID0 (JN,K) , K = 1, 3)

type: array of real variables

description: x, y, and z coordinates of each finite element grid point; a do loop is used to read these coordinates so that a new line is read for each new grid point:

```
DO 10 JN = 1, NNODE
  READ (3,*) ( GRID0 (JN,K) , K = 1, 3 )
10 CONTINUE
```

variable: NMODE

type: integer variable

description: number of mode shapes to be read

variable: JMODE

type: integer variable

description: index of mode shape to be read next

variable: (T1K(K) , K = 1, 6)

type: array of real variables

description: displacements and rotations of each finite element grid point; a triple do loop is used to read these coordinates so that a new line is read for each new grid point:

```
DO 30 IM = 1, NMODE
  READ (3,*) JMODE
  DO 20 IN = 1, NNODE
    READ (3,*) ( T1(K) , K = 1, 6 )
    DO 10 K = 1, 3
      UN(IN,K) = T1(K)
10    CONTINUE
20  CONTINUE
30  CONTINUE
```

Note that rotations T1K(4), T1K(5), T1K(6) are not used in the calculations.

5. EXAMPLES

In this section, some examples are presented. For each example, a brief description is given. The contents of the input file, parameter definition files, and output file are listed. A list of additional files created by the code is given. These examples are provided so that the user can verify the correct installation and operation of the code.

5.1 Example 1: F21 propfan — Steady flow

Description:

In this example, the steady flow around the F21 propfan is calculated using version 3 of the FPCAS3D code (Ref. 3). The propfan has 13 blades. For this steady calculation, only one blade passage is included in the calculations. The free-stream Mach number is 0.5, the advance ratio is 2.3 and the blade setting angle is 53 deg. The grid has 15 points on the blade surface in both the chordwise and spanwise directions; there are 11 points in the circumferential direction. A non-dimensional time step of 0.015 is used with 4 Newton sub-iterations at each time step. The code is run for a total of 600 time steps, which is sufficient to reach steady state.

para1.f:

```
PARAMETER ( IMX=56, JMX=11, KMX=24 )
```

para2.f:

```
PARAMETER ( NXPM=21, NRPM=21, NNODM=500 )
```

fpcas3d.input:

```
TITLE
F21 BLADE; STEADY RUN.
IEXTR      INUM      INI
0           4         0
MINF
0.5
ADV        BET3Q      SOMGA
2.3        54.01      2.0
NTMX       DTAU
600        0.015
NSTDY      FACTOR
0          0.0
RHUB0
0.45
IAIRFL
1
  ( ( TMPTTBL(I,J), I = 1, 15 ), J = 1, 15 )
    0.00000      0.00896      0.01322      0.01584      0.01761
    0.01842      0.01866      0.01824      0.01721      0.01593
    0.01395      0.01169      0.00919      0.00685      0.00000
```

39 lines deleted for brevity

0.00000	0.00896	0.01322	0.01584	0.01761
0.01842	0.01866	0.01824	0.01721	0.01593
0.01395	0.01169	0.00919	0.00685	0.00000

fpcas3d.blade.input:

```
*****
* F21 blade configuration 1: naca 0016 blade section (grdn12)
*****
+geom---+nblrow---+itheta---+-----+-----+-----+-----+
      2         1         1
+ninpts---+nexpts---+nblptz---+nblptr---+nblptt---+-----+
      0         0         15        15        11
+zinlet---+zexit---+-----+-----+-----+-----+
      -0.6       0.600
+ratin---+ratex---+ratbb---+ratblz---+ratblr---+ratblt---+rattip---+
      1.15       1.15       1.0       1.0       1.0       1.0       1.10
*****
+nhub---+ntip---+-----+-----+-----+-----+
      18         2
+-----+-----+-----+-----+-----+-----+-----+
-0.60  -0.3000 -0.2500 -0.2250 -0.2125 -0.2000 -0.1750  -0.150
-0.1250 -0.10  -0.075  -0.05  -0.025  0.000  0.0250  0.0500
0.200   0.6
0.450   0.450   0.450   0.450   0.450   0.450   0.450   0.450
0.450   0.450   0.450   0.450   0.450   0.450   0.450   0.450
0.450   0.450
+-----+-----+-----+-----+-----+-----+-----+
-0.600   0.600
1.5       1.5
*****
+nblld---+nblpl---+nppp---+-----+-----+-----+-----+
      13        15        15
+-----+-----+-----+-----+-----+-----+-----+

```

fpcas3d.mode.input:

```
NASTRAN MODEL
351
55.0 SETTING ANGLE
-0.122655E+01 -0.647716E+00 0.543327E+01
-0.958605E+00 -0.484295E+00 0.535619E+01
-0.695795E+00 -0.360734E+00 0.527894E+01

```

345 lines deleted for brevity

0.175599E+01	0.124670E+01	0.118627E+02
0.185145E+01	0.134304E+01	0.118355E+02
0.195413E+01	0.141949E+01	0.118104E+02
3		
1		
-0.215706E+00	0.218742E+00	-0.218704E+00
-0.199026E+01	0.000000E+00	0.207852E+01
-0.371169E+00	0.460544E+00	-0.179259E+00

•
345 lines deleted for brevity

•
-0.382106E+02 -0.273933E+02 0.557676E+02
-0.165240E+03 0.220175E+03 -0.634772E+01
-0.385890E+02 -0.271691E+02 0.565569E+02
2
-0.506236E+00 0.205176E+01 0.925785E+00
-0.843569E+01 0.000000E+00 0.196907E+01
-0.491026E+00 0.186282E+01 0.585961E+00

•
345 lines deleted for brevity

•
0.285083E+02 0.365781E+02 -0.291558E+03
0.370969E+03 -0.331670E+03 -0.207886E+02
0.317514E+02 0.341807E+02 -0.296961E+03
3
0.185382E+00 -0.383809E+01 -0.329603E+01
0.131264E+02 0.000000E+00 -0.185722E+01
0.650755E-02 -0.332906E+01 -0.216637E+01

•
345 lines deleted for brevity

•
-0.158338E+03 -0.156232E+03 -0.852136E+03
0.530542E+03 -0.535735E+03 -0.147507E+02
-0.145571E+03 -0.164916E+03 -0.879521E+03

fpcas3d.output:

F21 BLADE; STEADY RUN.

IEXTR = 0
INUM = 4
INI = 0
MINF = 0.5000
ADV = 2.3000
BET3Q = 54.0100
NTMX = 600
DTAU = 0.0150
NBS = 1
NSTDY = 0
SOMGA = 2.0000
FACTOR = 0.00000E+00
RHUB0 = 0.45000E+00
((TMPTTBL(I,J), I = 1, 15), J = 1, 15):
0.0000E+00 0.8960E-02 0.1322E-01 0.1584E-01 0.1761E-01
0.1842E-01 0.1866E-01 0.1824E-01 0.1721E-01 0.1593E-01
0.1395E-01 0.1169E-01 0.9190E-02 0.6850E-02 0.0000E+00

•
39 lines deleted for brevity

•
0.0000E+00 0.8960E-02 0.1322E-01 0.1584E-01 0.1761E-01
0.1842E-01 0.1866E-01 0.1824E-01 0.1721E-01 0.1593E-01
0.1395E-01 0.1169E-01 0.9190E-02 0.6850E-02 0.0000E+00
FROM NAST1, IN DEGREES, DBET=
0.99000E+00

FROM NAST1, RTIP=

0.12016E+02

NT= 0 UNDEFORMED BLADE

IMAX = 48

JMAX = 11

KMAX = 24

ILE = 19

ITE = 33

JTIP = 15

FROM GRID:

XXLE, YYLE, ZZLE =

-0.73255E-01 0.37500E+00 -0.17386E+00

XXTE, YYTE, ZZTE =

0.38571E-01 0.37500E+00 0.51349E-01

BETA =

0.52997E+02

NT=	1	NITER=	1	NBLOCK=	1		
TSRES=	0.4798E-03	SDPHI=	0.2533E-03	SDPHDT=	0.2452E-13		
NT=	1	NITER=	2	NBLOCK=	1		
TSRES=	0.1406E-03	SDPHI=	0.3794E-04	SDPHDT=	0.2526E-01		
NT=	1	NITER=	3	NBLOCK=	1		
TSRES=	0.5819E-04	SDPHI=	0.9967E-05	SDPHDT=	0.2429E-01		
NT=	1	NITER=	4	NBLOCK=	1		
TSRES=	0.4355E-04	SDPHI=	0.3896E-05	SDPHDT=	0.2471E-01		
NT=	1	NITER=	5	NBLOCK=	1		
TSRES=	0.3764E-04	SDPHI=	0.2171E-05	SDPHDT=	0.2466E-01		
NT=	2	NITER=	1	NBLOCK=	1		
TSRES=	0.6588E-03	SDPHI=	0.4032E-03	SDPHDT=	0.8229E-02		
NT=	2	NITER=	2	NBLOCK=	1		
TSRES=	0.2292E-03	SDPHI=	0.5650E-04	SDPHDT=	0.3243E-01		
NT=	2	NITER=	3	NBLOCK=	1		
TSRES=	0.1190E-03	SDPHI=	0.1481E-04	SDPHDT=	0.3141E-01		
NT=	2	NITER=	4	NBLOCK=	1		
TSRES=	0.1123E-03	SDPHI=	0.4934E-05	SDPHDT=	0.3191E-01		
NT=	2	NITER=	5	NBLOCK=	1		
TSRES=	0.1081E-03	SDPHI=	0.2516E-05	SDPHDT=	0.3187E-01		

20 lines deleted for brevity

NT=	5	NITER=	1	NBLOCK=	1		
TSRES=	0.5580E-03	SDPHI=	0.3959E-03	SDPHDT=	0.1331E-01		
NT=	5	NITER=	2	NBLOCK=	1		
TSRES=	0.3474E-03	SDPHI=	0.3869E-04	SDPHDT=	0.2824E-01		
NT=	5	NITER=	3	NBLOCK=	1		
TSRES=	0.2998E-03	SDPHI=	0.9625E-05	SDPHDT=	0.2878E-01		
NT=	5	NITER=	4	NBLOCK=	1		
TSRES=	0.3165E-03	SDPHI=	0.2998E-05	SDPHDT=	0.2878E-01		
NT=	5	NITER=	5	NBLOCK=	1		
TSRES=	0.3171E-03	SDPHI=	0.1357E-05	SDPHDT=	0.2876E-01		
NT=	596	NITER=	1	NBLOCK=	1		
TSRES=	0.3911E-03	SDPHI=	0.4608E-04	SDPHDT=	0.1585E-02		
NT=	596	NITER=	2	NBLOCK=	1		
TSRES=	0.3882E-03	SDPHI=	0.2710E-05	SDPHDT=	0.3065E-02		
NT=	596	NITER=	3	NBLOCK=	1		
TSRES=	0.3881E-03	SDPHI=	0.2011E-05	SDPHDT=	0.3128E-02		
NT=	596	NITER=	4	NBLOCK=	1		

```

TSRES= 0.3881E-03 SDPHI= 0.1898E-05 SDPHDT= 0.3156E-02
NT= 596 NITER= 5 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.1906E-05 SDPHDT= 0.3167E-02
NT= 597 NITER= 1 NBLOCK= 1
TSRES= 0.3911E-03 SDPHI= 0.4608E-04 SDPHDT= 0.1585E-02
NT= 597 NITER= 2 NBLOCK= 1
TSRES= 0.3882E-03 SDPHI= 0.2710E-05 SDPHDT= 0.3065E-02
NT= 597 NITER= 3 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.2011E-05 SDPHDT= 0.3128E-02
NT= 597 NITER= 4 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.1898E-05 SDPHDT= 0.3156E-02
NT= 597 NITER= 5 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.1906E-05 SDPHDT= 0.3167E-02

```

20 lines deleted for brevity

```

NT= 600 NITER= 1 NBLOCK= 1
TSRES= 0.3911E-03 SDPHI= 0.4608E-04 SDPHDT= 0.1585E-02
NT= 600 NITER= 2 NBLOCK= 1
TSRES= 0.3882E-03 SDPHI= 0.2710E-05 SDPHDT= 0.3065E-02
NT= 600 NITER= 3 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.2011E-05 SDPHDT= 0.3128E-02
NT= 600 NITER= 4 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.1898E-05 SDPHDT= 0.3156E-02
NT= 600 NITER= 5 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.1906E-05 SDPHDT= 0.3167E-02

```

```

( DCP(I), I = ILE, ITE ) AT K= 1
0.50523 0.94608 0.49758 0.24279 0.18446 0.27816 0.42450 0.50458
0.51120 0.49922 0.45464 0.39515 0.33983 0.19294 0.03824
( DCP(I), I = ILE, ITE ) AT K= 2
0.43516 0.90902 0.60486 0.32275 0.21749 0.23740 0.32999 0.41966
0.45192 0.44854 0.42934 0.40964 0.38214 0.22690 0.04801
( DCP(I), I = ILE, ITE ) AT K= 3
0.49104 1.00176 0.65260 0.36266 0.21294 0.18232 0.23174 0.30336
0.35915 0.38760 0.37711 0.38245 0.43182 0.30880 0.07740

```

27 lines deleted for brevity

```

( DCP(I), I = ILE, ITE ) AT K= 13
0.33858 0.72652 0.61339 0.50796 0.41355 0.33068 0.26322 0.21754
0.19731 0.20548 0.24470 0.30255 0.33105 0.26673 0.09651
( DCP(I), I = ILE, ITE ) AT K= 14
0.35668 0.76914 0.63041 0.47572 0.35963 0.27900 0.22954 0.19830
0.18412 0.19070 0.22373 0.28769 0.32011 0.22165 0.04536
( DCP(I), I = ILE, ITE ) AT K= 15
0.00000 0.00636 0.00954 0.01602 0.01243 0.01265 0.01304 0.01332
0.01334 0.01308 0.01323 0.01421 0.01540 0.01585 0.01140

```

POWER COEFFICIENT :

0.12514E+01

THRUST COEFFICIENT :

0.41645E+00

EFFICIENCY :

0.76541E+00

CP-STAR=

-0.21334E+01

additional output files:

fort.8	restart data
fort.51	time history of power and thrust coefficients
fort.53-57	time history of residuals
fort.71-74	blade surface grid and pressure distribution plot files
fort.81-83	grid and flow files in plot3d format

5.2 Example 2: F21 propfan — Frequency Domain Flutter**Description:**

In this example, frequency domain flutter calculations are performed for the F21 propfan blade (Ref. 3). For this flutter calculation, only in-phase (zero interblade phase angle) motion is considered. Only one blade passage is included in the calculations. Version 3 of the FPCAS3D code is used. The steady flow conditions and the grid used are the same as in example 1. As for the steady case, a non-dimensional time step of 0.015 is used with 4 Newton sub-iterations at each time step. The blade is moved in a pulse motion in the first mode. The non-dimensional duration of the pulse is 1.5 and calculations are continued until a non-dimensional time of 4.5 (total of 300 time steps).

For this example, additional post-processing of the results from FPCAS3D is required. The pulse response method is used to calculate the generalized aerodynamic forces required for flutter calculations. The post-processing code rootsfp.f incorporates this calculation together with a flutter calculation. A shell script links the output files from FPCAS3D with the appropriate unit numbers that are used to read these files in rootsfp.f. The input and output of rootsfp.f are also included in this section.

FPCAS3D must be run as many times as the number of modes in the flutter calculation. In this example, three modes are used and FPCAS3D is run thrice, for MOVEMODE=1, 2, and 3 respectively. The input and output files for the second and third runs are not listed here.

An additional post-processing code influnce.f implements only the pulse response method with no flutter calculation. This code can be used to generate the variation of generalized aerodynamic (force) coefficients for different vibration frequencies. Sample input and output for influnce.f are included in this section.

para1.f:

```
PARAMETER ( IMX=56, JMX=11, KMX=24 )
```

para2.f:

```
PARAMETER ( NXPM=21, NRPM=21, NNODM=500 )
```


fpcas3d.input:

```

TITLE
F21 BLADE; UNSTEADY RUN.
IEXTR      INUM      INI
0           4         1
MINF
0.5
ADV         BET3Q      SOMGA
2.3         54.01      1.5
NTMX        DTAU
300         0.015
NSTDY       FACTOR
2           2.0E-05
MOVEMODE
1
RHUB0
0.45
IAIRFL
1
  ( ( TMPTTBL(I,J), I = 1, 15 ), J = 1, 15 )
    0.00000      0.00896      0.01322      0.01584      0.01761
    0.01842      0.01866      0.01824      0.01721      0.01593
    0.01395      0.01169      0.00919      0.00685      0.00000
      .
      39 lines deleted for brevity
      .
    0.00000      0.00896      0.01322      0.01584      0.01761
    0.01842      0.01866      0.01824      0.01721      0.01593
    0.01395      0.01169      0.00919      0.00685      0.00000

```

fpcas3d.blade.input:

same as in example 1

fpcas3d.mode.input:

same as in example 1

fpcas3d.output:

```

F21 BLADE; UNSTEADY RUN.

IEXTR = 0
INUM = 4
INI = 1
MINF = 0.5000
ADV = 2.3000
BET3Q = 54.0100
NTMX = 300
DTAU = 0.0150
NBS = 1
NSTDY = 2
SOMGA = 1.5000
FACTOR = 0.20000E-04
RHUB0 = 0.45000E+00
  ( ( TMPTTBL(I,J), I = 1, 15 ), J = 1, 15 ):
0.0000E+00 0.8960E-02 0.1322E-01 0.1584E-01 0.1761E-01

```

```

0.1842E-01  0.1866E-01  0.1824E-01  0.1721E-01  0.1593E-01
0.1395E-01  0.1169E-01  0.9190E-02  0.6850E-02  0.0000E+00

```

39 lines deleted for brevity

```

0.0000E+00  0.8960E-02  0.1322E-01  0.1584E-01  0.1761E-01
0.1842E-01  0.1866E-01  0.1824E-01  0.1721E-01  0.1593E-01
0.1395E-01  0.1169E-01  0.9190E-02  0.6850E-02  0.0000E+00

```

FROM NAST1, IN DEGREES, DBET=

0.99000E+00

FROM NAST1, RTIP=

0.12016E+02

NT= 0 UNDEFORMED BLADE

IMAX = 48

JMAX = 11

KMAX = 24

ILE = 19

ITE = 33

JTIP = 15

FROM GRID:

XXLE, YYLE, ZZLE =

-0.73255E-01 0.37500E+00 -0.17386E+00

XXTE, YYTE, ZZTE =

0.38571E-01 0.37500E+00 0.51349E-01

BETA =

0.52997E+02

NBLOCK= 1

NT= 1 DEFORMED BLADE

```

NT=      1 NITER=  1 NBLOCK=  1
TSRES=   0.3911E-03 SDPHI=   0.4604E-04 SDPHDT=   0.1585E-02
NT=      1 NITER=  2 NBLOCK=  1
TSRES=   0.3882E-03 SDPHI=   0.2709E-05 SDPHDT=   0.3061E-02
NT=      1 NITER=  3 NBLOCK=  1
TSRES=   0.3881E-03 SDPHI=   0.2011E-05 SDPHDT=   0.3124E-02
NT=      1 NITER=  4 NBLOCK=  1
TSRES=   0.3881E-03 SDPHI=   0.1898E-05 SDPHDT=   0.3152E-02
NT=      1 NITER=  5 NBLOCK=  1
TSRES=   0.3881E-03 SDPHI=   0.1906E-05 SDPHDT=   0.3163E-02
NT=      2 NITER=  1 NBLOCK=  1
TSRES=   0.3911E-03 SDPHI=   0.4598E-04 SDPHDT=   0.1583E-02
NT=      2 NITER=  2 NBLOCK=  1
TSRES=   0.3881E-03 SDPHI=   0.2708E-05 SDPHDT=   0.3057E-02
NT=      2 NITER=  3 NBLOCK=  1
TSRES=   0.3881E-03 SDPHI=   0.2011E-05 SDPHDT=   0.3119E-02
NT=      2 NITER=  4 NBLOCK=  1
TSRES=   0.3881E-03 SDPHI=   0.1898E-05 SDPHDT=   0.3148E-02
NT=      2 NITER=  5 NBLOCK=  1
TSRES=   0.3881E-03 SDPHI=   0.1906E-05 SDPHDT=   0.3159E-02

```

70 lines deleted for brevity

```

NT=    300 NITER=  1 NBLOCK=  1
TSRES=   0.3911E-03 SDPHI=   0.4608E-04 SDPHDT=   0.1585E-02
NT=    300 NITER=  2 NBLOCK=  1
TSRES=   0.3882E-03 SDPHI=   0.2710E-05 SDPHDT=   0.3065E-02
NT=    300 NITER=  3 NBLOCK=  1

```

```

TSRES= 0.3881E-03 SDPHI= 0.2011E-05 SDPHDT= 0.3128E-02
NT= 300 NITER= 4 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.1898E-05 SDPHDT= 0.3156E-02
NT= 300 NITER= 5 NBLOCK= 1
TSRES= 0.3881E-03 SDPHI= 0.1906E-05 SDPHDT= 0.3167E-02

```

```

CP-STAR=
-0.21334E+01

```

additional output files:

```

fort.53-57    time history of residuals
fort.60       time history of blade motion (displacement)
fort.61       time history of generalized forces on blade

```

rootsfp input:

```

F21 DATA
      A0      P0
13341.0      14.7
      ADV      MINF      RTIP      BET3Q
      2.30      0.5      12.02      54.01
      NMODE      NBS      NOM
      3      1      2
      GM(1)      OM(1)
      1.0      287.05
      GM(2)      OM(2)
      1.0      480.27
      GM(3)      OM(3)
      1.0      798.40
STRDAMP
0.0
FREQ(IOM), IOM=1,NOM
400.0 550.0

```

In the above, RTIP is calculated by FPCAS3D from the finite element grid. NOM is the number of frequencies to be used in the root-finding algorithm; these frequencies are input as (FREQ(IOM), IOM = 1, NOM) in Hz. STRDAMP is the amount of structural damping.

rootsfp output:

```

*****
*      Aeroelastic stability analysis      *
*      using normal mode structural model  *
*      in FREQUENCY DOMAIN                *
*      with Full Potential aerodynamic model *
*****
+++++++
+ atmospheric conditions
-----
+ pressure=14.699999999999999
+ speed of sound (in/sec)=13341.
+ density=1.156294878589626E-7
+++++++
*      operating conditions:
-----
* rotor speed(rpm)=7238.479346017411
* rotor speed(rad/sec)=758.0117845536552

```

```
* Mach no.= 0.5
* advance ratio (J).= 2.299999999999997
* tip radius (inches)=12.019999999999998
* setting angle (deg.) =54.009999999999999
```

```
-----
analysis for 1 angles:
analysis using 3 modes:
```

mode	freq(hz)	structural model gen. mass
1	287.05	0.1000E+01
1	2.38	0.4980E+04
2	480.27	0.1000E+01
2	3.98	0.4980E+04
3	798.40	0.1000E+01
3	6.62	0.4980E+04

```
-----
analysis using 2 frequencies.
```

```
iom, om(iom), freq(hz):
```

```
1 0.45288E+01 0.40000E+03
2 0.62271E+01 0.55000E+03
```

```
#####
movemode index = 1
```

```
READING MOTION FILE
```

```
101 LINES IN MOTION FILE
```

```
DELT = 1.5000000000000001E-2
```

```
READING FORCE FILE(S)
```

```
301 LINES IN FORCE FILE(S)
```

```
frequency = 4.528829166767025
```

```
phase index, mode index = 2*1 qij =
```

```
-0.22916E+04 -0.43129E+04
```

```
phase index, mode index = 1, 2 qij =
```

```
-0.83328E+03 -0.13443E+03
```

```
phase index, mode index = 1, 3 qij =
```

```
-0.17969E+04 -0.16630E+04
```

```
frequency = 6.227140104304652
```

```
phase index, mode index = 2*1 qij =
```

```
-0.14897E+04 -0.56636E+04
```

```
phase index, mode index = 1, 2 qij =
```

```
-0.93960E+03 -0.19414E+03
```

```
phase index, mode index = 1, 3 qij =
```

```
-0.18292E+04 -0.23948E+04
```

```

      .
several lines deleted for brevity
      .
```

```
#####
```

```
eigensolution for ip = 1
```

```
#####
```

```

      .
several lines deleted for brevity
      .
```

```

all eigenvalues (hz):
  1  -0.19683E+02    0.75246E+03
  2  -0.23742E+02    0.46901E+03
  3  -0.17579E+02    0.30348E+03

root 2 is closest to center of interpolation

```

influnce input and output:

```

enter movemode number
1
ENTER NUMBER OF BLADES IN CALCULATION.
1
ENTER INDEX OF BLADE THAT WAS MOVED.
1
ENTER NUMBER OF MODES IN CALCULATION.
3

READING MOTION FILE
101 LINES IN MOTION FILE
DELT = 1.500000000000001E-2

READING FORCE FILE(S)
301 LINES IN FORCE FILE(S)

WORKING ...

DONE !!

```

The above execution of influnce code results in a file `movemode_1.fort81`, which contains some of the generalized aerodynamic coefficients. To obtain all the generalized aerodynamic coefficients, the influnce code must be executed two more times with movemode number input as 2 and 3. These two runs will result in two additional files `movemode_2.fort81` and `movemode_3.fort81` being created, which contain the remaining generalized aerodynamic coefficients.

5.3 Example 3: F21 propfan — Time Domain Flutter

Description:

In this example, time domain flutter calculations are performed for the F21 propfan blade (Ref. 4). For this flutter calculation, only in-phase motion is considered. Only one blade passage is included in the calculations. Version 6 of the FPCAS3D code is used. The steady flow conditions and the grid used are the same as in example 1, except that the advance ratio is 2.7. A steady solution is obtained, first as in example 1. Then, a time domain flutter calculation is performed. As before, a non-dimensional time step of 0.015 is used with 4 Newton sub-iterations at each time step. The blade is given a small initial velocity in each mode. The calculations are continued until a non-dimensional time of 15.0 (total of 1000 time steps).

para1.f:

```
PARAMETER ( IMX=56, JMX=11, KMX=24 )
```

para2.f:

```
PARAMETER ( NXPM=21, NRPM=21, NNODM=500 )
```

fpcas3d.input:

TITLE

F21 BLADE; TIME DOMAIN FLUTTER RUN.

```
IEXTR      INUM      INI
0           4         1
```

MINF

0.5

```
ADV        BET3Q      SOMGA
2.7        54.01      1.5
```

```
NTMX       DTAU
1000       0.015
```

```
NSTDY      FACTOR
2          2.0E-05
```

RHUB0

0.45

```
P0         A0
14.7       13341.0
```

NMODE

3

```
( OM(IM), IM = 1, NMODE )
```

```
287.05     480.27     798.40
```

```
( GM(IM), IM = 1, NMODE )
```

```
1.0        1.0        1.0
```

IAIRFL

1

```
( ( TMPTTBL(I,J), I = 1, 15 ), J = 1, 15 )
```

```
0.00000    0.00896    0.01322    0.01584    0.01761
0.01842    0.01866    0.01824    0.01721    0.01593
0.01395    0.01169    0.00919    0.00685    0.00000
```

39 lines deleted for brevity

```
0.00000    0.00896    0.01322    0.01584    0.01761
0.01842    0.01866    0.01824    0.01721    0.01593
0.01395    0.01169    0.00919    0.00685    0.00000
```

fpcas3d.blade.input:

same as in example 1

fpcas3d.mode.input:

same as in example 1

fpcas3d.output:

F21 BLADE; TIME DOMAIN FLUTTER RUN

```
IEXTR = 0
INUM  = 4
INI   = 1
```

```

MINF =      0.5000
ADV =      2.7000
BET3Q =    54.0100
NTMX =    1000
DTAU =      0.0150
NBS =      1
NSTDY =    2
SOMGA =    1.5000
FACTOR =   0.20000E-04
RHUB0 =
          0.45000E+00
P0, A0 :
0.1470E+02  0.1334E+05
NMODE = 3
OM(IM), IM = 1, NMODE :
0.2870E+03  0.4803E+03  0.7984E+03
GM(IM), IM = 1, NMODE :
0.1000E+01  0.1000E+01  0.1000E+01
( ( TMPTTBL(I,J), I = 1, 15 ), J = 1, 15 ):
0.0000E+00  0.8960E-02  0.1322E-01  0.1584E-01  0.1761E-01
0.1842E-01  0.1866E-01  0.1824E-01  0.1721E-01  0.1593E-01
0.1395E-01  0.1169E-01  0.9190E-02  0.6850E-02  0.0000E+00

```

39 lines deleted for brevity

```

0.0000E+00  0.8960E-02  0.1322E-01  0.1584E-01  0.1761E-01
0.1842E-01  0.1866E-01  0.1824E-01  0.1721E-01  0.1593E-01
0.1395E-01  0.1169E-01  0.9190E-02  0.6850E-02  0.0000E+00
FROM NAST1, IN DEGREES, DBET=

```

0.99000E+00

FROM NAST1, RTIP=

0.12016E+02

NT= 0 UNDEFORMED BLADE

IMAX = 48

JMAX = 11

KMAX = 24

ILE = 19

ITE = 33

JTIP = 15

FROM GRID:

XXLE, YYLE, ZZLE =

-0.73255E-01 0.37500E+00 -0.17386E+00

XXTE, YYTE, ZZTE =

0.38571E-01 0.37500E+00 0.51349E-01

BETA =

0.52997E+02

```

NT=      1 NITER= 1 NBLOCK= 1
TSRES=   0.1175E-03 SDPHI=  0.5442E-05 SDPHDT=  0.1834E-03
NT=      1 NITER= 2 NBLOCK= 1
TSRES=   0.1172E-03 SDPHI=  0.8901E-06 SDPHDT=  0.3613E-03
NT=      1 NITER= 3 NBLOCK= 1
TSRES=   0.1173E-03 SDPHI=  0.8627E-06 SDPHDT=  0.3698E-03
NT=      1 NITER= 4 NBLOCK= 1
TSRES=   0.1173E-03 SDPHI=  0.8567E-06 SDPHDT=  0.3739E-03
NT=      1 NITER= 5 NBLOCK= 1
TSRES=   0.1173E-03 SDPHI=  0.8584E-06 SDPHDT=  0.3753E-03

```

```

NT=      1 NITER=  1 NBLOCK=  1
TSRES=   0.1172E-03 SDPHI=  0.1107E-05 SDPHDT=  0.3756E-03
NT=      1 NITER=  2 NBLOCK=  1
TSRES=   0.1171E-03 SDPHI=  0.8668E-06 SDPHDT=  0.3947E-03
NT=      1 NITER=  3 NBLOCK=  1
TSRES=   0.1172E-03 SDPHI=  0.8579E-06 SDPHDT=  0.3942E-03
NT=      1 NITER=  4 NBLOCK=  1
TSRES=   0.1171E-03 SDPHI=  0.8592E-06 SDPHDT=  0.3943E-03
NT=      1 NITER=  5 NBLOCK=  1
TSRES=   0.1171E-03 SDPHI=  0.8576E-06 SDPHDT=  0.3943E-03

```

160 lines deleted for brevity

```

NT= 1000 NITER=  1 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.5361E-05 SDPHDT=  0.1821E-03
NT= 1000 NITER=  2 NBLOCK=  1
TSRES=  0.1173E-03 SDPHI=  0.8795E-06 SDPHDT=  0.3531E-03
NT= 1000 NITER=  3 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8621E-06 SDPHDT=  0.3595E-03
NT= 1000 NITER=  4 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8528E-06 SDPHDT=  0.3626E-03
NT= 1000 NITER=  5 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8583E-06 SDPHDT=  0.3640E-03
NT= 1000 NITER=  1 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8524E-06 SDPHDT=  0.3641E-03
NT= 1000 NITER=  2 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8577E-06 SDPHDT=  0.3642E-03
NT= 1000 NITER=  3 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8527E-06 SDPHDT=  0.3641E-03
NT= 1000 NITER=  4 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8573E-06 SDPHDT=  0.3643E-03
NT= 1000 NITER=  5 NBLOCK=  1
TSRES=  0.1174E-03 SDPHI=  0.8530E-06 SDPHDT=  0.3641E-03

```

CP-STAR=

-0.21334E+01

additional output files:

```

fort.53-57   time history of residuals
fort.60      time history of blade motion (modal displacements)
fort.71      time history of generalized forces on blade

```

5.4 Example 4: SR3C-X2 propfan — Steady flow

Description:

In this example, the steady flow around the SR3C-X2 propfan is calculated using version 3 of the FPCAS3D code (Ref. 3). This example is very similar to example 1 and it is included here only because the steady solution generated in this example is used in the next two examples. The propfan has 8 blades. For this steady calculation, only one blade passage is included in the calculations. The freestream Mach number is 0.7, the advance ratio is 3.55 and the blade setting

angle is 61.2 deg. The grid has 15 points on the blade surface in both the chordwise and spanwise directions; there are 11 points in the circumferential direction. A non-dimensional time step of 0.02 is used with 4 Newton sub-iterations at each time step. The code is run for a total of 600 time steps, which is sufficient to reach steady state.

para1.f:

```
PARAMETER ( IMX=56, JMX=11, KMX=24 )
```

para2.f:

```
PARAMETER ( NXPM=21, NRPM=21, NNODM=500 )
```

fpcas3d.input:

```
TITLE
SR3CX2 BLADE; STEADY RUN.
IEXTR      INUM      INI
0          4          0
MINF
0.7
ADV        BET3Q      SOMGA
3.55       61.2       2.0
NTMX       DTAU
600        0.02
NSTDY      FACTOR
0          0.0
RHUB0
0.325
IAIRFL
0
( TMAX(J), J = 1, 15 )
0.085 0.073 0.055 0.049 0.040
0.037 0.033 0.030 0.027 0.024
0.021 0.0205 0.02 0.02 0.02
( CHD16(J), J = 1, 15 )
0.    0.240 0.340 0.390 0.435
0.470 0.492 0.500 0.490 0.465
0.430 0.395 0.295 0.155 0.01
```

fpcas3d.blade.input:

```
*****
* sr3 blade configuration 1: naca 0016 blade section (grdn12) : mesh input
*****
+geom---+nblrow---+itheta---+-----+-----+-----+-----+-----+
          2          1          1
+ninpts---+nexpts---+nblptz---+nblptr---+nblptt---+-----+-----+
          0          0          15          15          11
+zinlet---+zexit---+-----+-----+-----+-----+-----+
        -0.6        0.600
+ratin---+ratex---+ratbb---+ratblz---+ratblr---+ratblt---+rattip---+-----+
        1.15        1.15        1.0        1.0        1.0        1.0        1.10
*****
+nhub---+ntip---+-----+-----+-----+-----+-----+
        18          2
+-----+-----+-----+-----+-----+-----+-----+
-0.60  -0.3000  -0.2500  -0.2250  -0.2125  -0.2000  -0.1750  -0.150
```

```

-.1250  -.10  -0.075  -0.05  -0.025  0.000  0.0250  0.0500
.200    0.6
0.325   0.325  0.325  0.325  0.325  0.325  0.325  0.325
0.325   0.325  0.325  0.325  0.325  0.325  0.325  0.325
0.325   0.325
+-----+-----+-----+-----+-----+-----+-----+
-0.600   0.600
1.5      1.5
*****
+nbld-----+nbldpl-----+nppp-----+-----+-----+-----+
      8          15          15
+-----+-----+-----+-----+-----+-----+

```

fpcas3d.mode.input:

NASTRAN MODEL

```

228
61.2 SETTING ANGLE
-0.699, 3.78E-2, 1.7
-0.3994, 2.16E-2, 1.7
-0.1997, 1.07E-2, 1.7

```

222 lines deleted for brevity

```

2.9451, 2.5496, 12.25
3.1181, 2.6745, 12.25
3.2906, 2.7913, 12.25
3
1 221.082, 2.408413E-5
0., 0., 0., 0., 0., 0.
0., 0., 0., 0., 0., 0.
0., 0., 0., 0., 0., 0.

```

222 lines deleted for brevity

```

-0.4955444, 0.8732229, -0.171114, 6.617669E-3, 0., 0.3687983
-0.5403824, 0.9353858, -0.1869332, -5.394974E-2, 8.613998E-2, 0.3609418
-0.5841199, 1., -0.2032966, 0., 3.973398E-3, 0.399895
2 402.1287, 2.444044E-5
0., 0., 0., 0., 0., 0.
0., 0., 0., 0., 0., 0.
0., 0., 0., 0., 0., 0.

```

222 lines deleted for brevity

```

-0.7769125, 0.5828328, -5.463228E-3, 0.5090338, 0., 1.237072
-0.9233983, 0.7859724, -3.896407E-2, 0.2050837, 0.4358469, 1.194069
-1.06826, 1., -7.816583E-2, 0., 0.7318393, 1.153952
3 698.2002, 1.445758E-5
0., 0., 0., 0., 0., 0.
0., 0., 0., 0., 0., 0.
0., 0., 0., 0., 0., 0.

```

222 lines deleted for brevity

```

-0.2114946, 0.3936796, -0.1211723, 0.9387482, 0., 1.765229
-0.4192395, 0.6821609, -0.1912199, 0.3283257, 0.8994851, 1.713123

```

-0.6343095, 1., -0.2746055, 0., 1.38141, 1.709341

fpcas3d.output:

SR3CX2 BLADE; STEADY RUN

```

IEXTR = 0
INUM = 4
INI = 0
MINF = 0.7000
ADV = 3.5500
BET3Q = 61.2000
NTMX = 600
DTAU = 0.0200
NBS = 1
NSTDY = 0
SOMGA = 2.0000
FACTOR = 0.00000E+00
RHUB0 = 0.32500E+00
TMAX(J), J = 1, 15 :
0.8500E-01 0.7300E-01 0.5500E-01 0.4900E-01 0.4000E-01
0.3700E-01 0.3300E-01 0.3000E-01 0.2700E-01 0.2400E-01
0.2100E-01 0.2050E-01 0.2000E-01 0.2000E-01 0.2000E-01
CHD16(J), J = 1, 15 :
0.0000E+00 0.2400E+00 0.3400E+00 0.3900E+00 0.4350E+00
0.4700E+00 0.4920E+00 0.5000E+00 0.4900E+00 0.4650E+00
0.4300E+00 0.3950E+00 0.2950E+00 0.1550E+00 0.1000E-01
FROM NAST1, IN DEGREES, DBET=
0.00000E+00
FROM NAST1, RTIP=
0.12458E+02
NT= 0 UNDEFORMED BLADE
IMAX = 47
JMAX = 11
KMAX = 22
ILE = 20
ITE = 34
JTIP = 15

FROM GRID:
XXLE, YYLE, ZZLE =
-0.45218E-01 0.37500E+00 -0.66245E-01
XXTE, YYTE, ZZTE =
0.10285E+00 0.37500E+00 0.15224E+00
BETA = 0.61091E+02

NT= 1 NITER= 1 NBLOCK= 1
TSRES= 0.8375E-03 SDPHI= 0.4406E-03 SDPHDT= 0.1937E-13
NT= 1 NITER= 2 NBLOCK= 1
TSRES= 0.2014E-03 SDPHI= 0.7529E-04 SDPHDT= 0.3300E-01
NT= 1 NITER= 3 NBLOCK= 1
TSRES= 0.7166E-04 SDPHI= 0.1994E-04 SDPHDT= 0.3090E-01
NT= 1 NITER= 4 NBLOCK= 1
TSRES= 0.4087E-04 SDPHI= 0.6741E-05 SDPHDT= 0.3167E-01
NT= 1 NITER= 5 NBLOCK= 1
TSRES= 0.3122E-04 SDPHI= 0.3895E-05 SDPHDT= 0.3151E-01
```

•
80 lines deleted for brevity
•

```

NT= 600 NITER= 1 NBLOCK= 1
TSRES= 0.3899E-03 SDPHI= 0.7365E-05 SDPHDT= 0.1872E-03
NT= 600 NITER= 2 NBLOCK= 1
TSRES= 0.3898E-03 SDPHI= 0.1221E-05 SDPHDT= 0.3640E-03
NT= 600 NITER= 3 NBLOCK= 1
TSRES= 0.3898E-03 SDPHI= 0.1192E-05 SDPHDT= 0.3707E-03
NT= 600 NITER= 4 NBLOCK= 1
TSRES= 0.3898E-03 SDPHI= 0.1185E-05 SDPHDT= 0.3732E-03
NT= 600 NITER= 5 NBLOCK= 1
TSRES= 0.3898E-03 SDPHI= 0.1187E-05 SDPHDT= 0.3742E-03

```

```

( DCP(I), I = ILE, ITE ) AT K= 1
0.09378 0.20682 0.18194 0.16726 0.18086 0.19610 0.21249 0.22081
0.21396 0.20351 0.19517 0.16107 0.09698 0.04038 0.00647
( DCP(I), I = ILE, ITE ) AT K= 2
0.06003 0.15295 0.17204 0.17058 0.18860 0.21005 0.23207 0.24564
0.24400 0.24272 0.24137 0.20291 0.12777 0.03809 -0.00347
( DCP(I), I = ILE, ITE ) AT K= 3
0.04851 0.13521 0.16835 0.17354 0.19461 0.21883 0.24400 0.26156
0.26969 0.28040 0.28754 0.25298 0.17229 0.06296 0.00299
( DCP(I), I = ILE, ITE ) AT K= 4
0.04701 0.13761 0.17563 0.18023 0.20035 0.22321 0.24806 0.26885
0.28316 0.30285 0.32291 0.29644 0.21320 0.09369 0.01405
( DCP(I), I = ILE, ITE ) AT K= 5
0.05084 0.14720 0.18734 0.19171 0.21055 0.23158 0.25322 0.27441
0.29278 0.31543 0.34230 0.33008 0.25485 0.13224 0.03069
( DCP(I), I = ILE, ITE ) AT K= 6
0.05784 0.16122 0.20215 0.20934 0.22680 0.24485 0.26623 0.28946
0.30909 0.32931 0.35509 0.34789 0.27682 0.15590 0.04295
( DCP(I), I = ILE, ITE ) AT K= 7
0.07035 0.18154 0.21901 0.22966 0.24733 0.26698 0.28912 0.30978
0.32470 0.34227 0.36444 0.35321 0.28249 0.16726 0.05032
( DCP(I), I = ILE, ITE ) AT K= 8
0.08707 0.20999 0.24102 0.25190 0.27047 0.29089 0.30996 0.32620
0.33879 0.35424 0.37333 0.35989 0.28849 0.17452 0.05387
( DCP(I), I = ILE, ITE ) AT K= 9
0.10970 0.24628 0.26634 0.27910 0.29714 0.31404 0.32967 0.34276
0.35307 0.36618 0.38069 0.36360 0.29123 0.17822 0.05601
( DCP(I), I = ILE, ITE ) AT K= 10
0.14057 0.29433 0.29684 0.30762 0.32242 0.33669 0.34776 0.35365
0.35891 0.37122 0.38313 0.36152 0.28786 0.17691 0.05598
( DCP(I), I = ILE, ITE ) AT K= 11
0.18141 0.35688 0.33628 0.34198 0.35027 0.35739 0.36176 0.36382
0.36566 0.37168 0.37300 0.34517 0.27809 0.17736 0.05803
( DCP(I), I = ILE, ITE ) AT K= 12
0.23320 0.43381 0.37842 0.37679 0.37851 0.37708 0.37239 0.36538
0.35777 0.35490 0.35470 0.32792 0.25469 0.15443 0.04895
( DCP(I), I = ILE, ITE ) AT K= 13
0.29099 0.52042 0.42636 0.40488 0.39148 0.37460 0.35384 0.33122
0.31435 0.31434 0.32168 0.29284 0.20642 0.10715 0.03168
( DCP(I), I = ILE, ITE ) AT K= 14
0.42085 0.66907 0.45540 0.38642 0.34016 0.30366 0.27340 0.24839
0.23409 0.23813 0.24155 0.19413 0.09414 0.01219 -0.00549
( DCP(I), I = ILE, ITE ) AT K= 15
0.00000 0.00597 0.00697 0.00786 0.00834 0.00855 0.00857 0.00848

```

```

0.00831  0.00810  0.00808  0.00806  0.00701  0.00504  0.00777

POWER COEFFICIENT :
  0.14134E+01
THRUST COEFFICIENT :
  0.33966E+00
EFFICIENCY :
  0.85312E+00

CP-STAR=
      -0.77907E+00

```

additional output files:

```

fort.8      restart data
fort.51     time history of power and thrust coefficients
fort.53-57  time history of residuals
fort.71-74  blade surface grid and pressure distribution plot files
fort.81-83  grid and flow files in plot3d format

```

5.5 Example 5: SR3C-X2 propfan — Frequency Domain Flutter

Description:

In this example, frequency domain flutter calculations are performed for the SR3C-X2 propfan blade (Ref. 3). For this flutter calculation, phase angles of 0 and 180 deg. are considered (in-phase and out-of-phase motions). Two blade passages are included in the calculations. Version 2 of the FPCAS3D code is used. The steady flow conditions and the grid used are the same as in example 4. As for the steady case, a non-dimensional time step of 0.02 is used with 4 Newton sub-iterations at each time step. The blade is moved in a pulse motion in the first mode. The non-dimensional duration of the pulse is 2.0 and calculations are continued until a non-dimensional time of 6.0 (total of 300 time steps).

For this example, additional post-processing of the results from FPCAS3D is required. The combined pulse response and influence coefficient method is used to calculate the generalized aerodynamic forces required for flutter calculations. The post-processing code rootsfp.f incorporates this calculation together with a flutter calculation. A shell script links the output files from FPCAS3D with the appropriate unit numbers that are used to read these files in rootsfp.f. The input and output of rootsfp.f are also included in this section.

FPCAS3D must be run as many times as the number of modes in the flutter calculation. In this example, three modes are used and FPCAS3D is run thrice, for MOVEMODE=1, 2, and 3 respectively. The input and output files for the second and third runs are not listed here.

An additional post-processing code `influnce.f` implements only the combined pulse response and influence coefficient method with no flutter calculation. This code can be used to generate the variation of generalized aerodynamic (force) coefficients for different vibration frequencies and phase angles. Sample input and output for `influnce.f` are included in this section.

para1.f:

```
PARAMETER ( IMX=56, JMX=11, KMX=24 )
```

para2.f:

```
PARAMETER ( NXPM=21, NRPM=21, NNODM=500 )
```

para3.f:

```
PARAMETER ( NPS=2 )
```

fpcas3d.input:

```
TITLE
SR3CX2 BLADE; UNSTEADY RUN.
IEXTR      INUM      INI
0           4         1
MINF
0.7
ADV         BET3Q      SOMGA
3.55        61.2       2.0
NTMX        DTAU       NBS
300         0.02       2
NSTDY       FACTOR
2           0.01
( IMOV(NBLADE), NBLADE = 1, NBS )
1 0
MOVEMODE
1
RHUB0
0.325
IAIRFL
0
( TMAX(J), J = 1, 15 )
0.085 0.073 0.055 0.049 0.040
0.037 0.033 0.030 0.027 0.024
0.021 0.0205 0.02 0.02 0.02
( CHD16(J), J = 1, 15 )
0.    0.240 0.340 0.390 0.435
0.470 0.492 0.500 0.490 0.465
0.430 0.395 0.295 0.155 0.01
```

fpcas3d.blade.input:

same as in example 4

fpcas3d.mode.input:

same as in example 4

fpcas3d.output:

SR3CX2 BLADE; UNSTEADY RUN

```
IEXTR = 0
INUM = 4
INI = 1
MINF = 0.7000
ADV = 3.5500
BET3Q = 61.2000
NTMX = 300
DTAU = 0.0200
NBS = 2
NSTDY = 2
SOMGA = 2.0000
FACTOR = 0.10000E-01
IMOV(NBLADE), NBLADE = 1, NBS :
1 0
MOVEMODE = 1
RHUB0 = 0.32500E+00
TMAX(J), J = 1, 15 :
0.8500E-01 0.7300E-01 0.5500E-01 0.4900E-01 0.4000E-01
0.3700E-01 0.3300E-01 0.3000E-01 0.2700E-01 0.2400E-01
0.2100E-01 0.2050E-01 0.2000E-01 0.2000E-01 0.2000E-01
CHD16(J), J = 1, 15 :
0.0000E+00 0.2400E+00 0.3400E+00 0.3900E+00 0.4350E+00
0.4700E+00 0.4920E+00 0.5000E+00 0.4900E+00 0.4650E+00
0.4300E+00 0.3950E+00 0.2950E+00 0.1550E+00 0.1000E-01
FROM NAST1, IN DEGREES, DBET=
0.00000E+00
FROM NAST1, RTIP=
0.12458E+02
NT= 0 UNDEFORMED BLADE
IMAX = 47
JMAX = 11
KMAX = 22
ILE = 20
ITE = 34
JTIP = 15
FROM GRID:
XXLE, YYLE, ZZLE =
-0.45218E-01 0.37500E+00 -0.66245E-01
XXTE, YYTE, ZZTE =
0.10285E+00 0.37500E+00 0.15224E+00
BETA =
0.61091E+02
NBLOCK= 1
NT= 1 DEFORMED BLADE
NBLOCK= 2
NT= 1 DEFORMED BLADE
NT= 1 NITER= 1 NBLOCK= 1
TSRES= 0.3899E-03 SDPHI= 0.7332E-05 SDPHDT= 0.1872E-03
NT= 1 NITER= 1 NBLOCK= 2
TSRES= 0.3899E-03 SDPHI= 0.7330E-05 SDPHDT= 0.1872E-03
```

```

NT=      1 NITER=  2 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1220E-05 SDPHDT=  0.3615E-03
NT=      1 NITER=  2 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1220E-05 SDPHDT=  0.3613E-03
NT=      1 NITER=  3 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1192E-05 SDPHDT=  0.3682E-03
NT=      1 NITER=  3 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1192E-05 SDPHDT=  0.3681E-03
NT=      1 NITER=  4 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1185E-05 SDPHDT=  0.3706E-03
NT=      1 NITER=  4 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1185E-05 SDPHDT=  0.3706E-03
NT=      1 NITER=  5 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1187E-05 SDPHDT=  0.3717E-03
NT=      1 NITER=  5 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1187E-05 SDPHDT=  0.3716E-03

```

160 lines deleted for brevity

```

NT=    300 NITER=  1 NBLOCK=  1
TSRES=   0.3899E-03 SDPHI=  0.7365E-05 SDPHDT=  0.1872E-03
NT=    300 NITER=  1 NBLOCK=  2
TSRES=   0.3899E-03 SDPHI=  0.7368E-05 SDPHDT=  0.1873E-03
NT=    300 NITER=  2 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1221E-05 SDPHDT=  0.3640E-03
NT=    300 NITER=  2 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1221E-05 SDPHDT=  0.3641E-03
NT=    300 NITER=  3 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1192E-05 SDPHDT=  0.3707E-03
NT=    300 NITER=  3 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1192E-05 SDPHDT=  0.3708E-03
NT=    300 NITER=  4 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1185E-05 SDPHDT=  0.3732E-03
NT=    300 NITER=  4 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1185E-05 SDPHDT=  0.3733E-03
NT=    300 NITER=  5 NBLOCK=  1
TSRES=   0.3898E-03 SDPHI=  0.1187E-05 SDPHDT=  0.3742E-03
NT=    300 NITER=  5 NBLOCK=  2
TSRES=   0.3898E-03 SDPHI=  0.1187E-05 SDPHDT=  0.3743E-03

```

CP-STAR=

-0.77907E+00

additional output files:

fort.53-57 time history of residuals
fort.60 time history of blade motion (displacement)
fort.61-62 time history of generalized forces on blades

rootsfp input:

```

SR3CX2 DATA
      A0          P0
13560.0      13.102
      ADV         MINF      RTIP      BET3Q
      3.55        0.7      12.458      61.2
      NMODE       NBS       NOM
      3           2         2
      GM(1)       OM(1)

```



```

2.408413E-5  221.082
      GM(2)      OM(2)
2.444044E-5  402.1287
      GM(3)      OM(3)
1.445758E-5  698.2002
STRDAMP
0.0
FREQ(IOM), IOM=1,NOM
200.0 350.0

```

In the above, RTIP is calculated by FPCAS3D from the finite element grid. NOM is the number of frequencies to be used in the root-finding algorithm; these frequencies are input as (FREQ(IOM), IOM = 1, NOM) in Hz. STRDAMP is the amount of structural damping.

rootsfp output:

```

*****
*      Aeroelastic stability analysis      *
*      using normal mode structural model  *
*              in FREQUENCY DOMAIN        *
*      with Full Potential aerodynamic model      *
*****
+++++
+  atmospheric conditions
-----
+  pressure=13.10199999999998
+  speed of sound (in/sec)=13560.
+  density=9.975765960964404E-8
+++++
*      operating conditions:
-----
*  rotor speed(rpm)=6438.760997514968
*  rotor speed(rad/sec)=674.2654749337817
*  Mach no.= 0.6999999999999993
*  advance ratio (J).= 3.549999999999997
*  tip radius (inches)=12.45800000000003
*  setting angle (deg.) =61.20000000000005
-----
      analysis for 2  angles:
      analysis using 3  modes:

      structural model
mode    freq(hz)    gen. mass
-----
  1      221.08      0.2408E-04
  1       2.06      0.1249E+00
  2      402.13      0.2444E-04
  2       3.75      0.1267E+00
  3      698.20      0.1446E-04
  3       6.51      0.7496E-01
-----

analysis using 2 frequencies.
iom, om(iom), freq(hz):
  1  0.23090E+01  0.20000E+03
  2  0.40408E+01  0.35000E+03
#####

```

```

movemode index = 1

READING MOTION FILE
100 LINES IN MOTION FILE
DELT = 2.0000000000000001E-2

READING FORCE FILE(S)
301 LINES IN FORCE FILE(S)
frequency = 2.309024264213676
phase index, mode index = 2*1 qij =
-0.26432E+00 -0.89449E-01
phase index, mode index = 1, 2 qij =
0.12763E+00 -0.33062E-01
phase index, mode index = 1, 3 qij =
0.14507E+00 0.16861E-01
phase index, mode index = 2, 1 qij =
-0.32325E+00 -0.15853E-01
phase index, mode index = 2*2 qij =
0.18278E+00 -0.99929E-01
phase index, mode index = 2, 3 qij =
0.14265E+00 0.23949E-01

```

.

several lines deleted for brevity

.

```

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
eigensolution for ip = 1
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

```

.

several lines deleted for brevity

.

```

all eigenvalues (hz):
1 -0.54889E+02 0.61297E+03
2 -0.10400E+03 0.39558E+03
3 0.53876E+01 0.29302E+03

```

root 3 is closest to center of interpolation

```

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
eigensolution for ip = 2
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

```

.

several lines deleted for brevity

.

```

all eigenvalues (hz):
1 -0.47086E+02 0.60742E+03
2 -0.12104E+03 0.40502E+03
3 0.24085E+02 0.28809E+03

```

root 3 is closest to center of interpolation

influnce input and output:

```
enter movemode number
1 ENTER NUMBER OF BLADES IN CALCULATION.
2 ENTER INDEX OF BLADE THAT WAS MOVED.
1 ENTER NUMBER OF MODES IN CALCULATION.
3

READING MOTION FILE
100 LINES IN MOTION FILE
DELT = 2.0000000000000001E-2

READING FORCE FILE(S)
301 LINES IN FORCE FILE(S)

WORKING ...

DONE !!
```

The above execution of influnce code results in files `movemode_1.fort81` and `movemode_1.fort82`, which contain some of the generalized aerodynamic coefficients. To obtain all the generalized aerodynamic coefficients, the influnce code must be executed two more times with movemode number input as 2 and 3. These two runs will result in four additional files `movemode_2.fort81`, `movemode_2.fort82`, `movemode_3.fort81` and `movemode_3.fort82` being created, which contain the remaining generalized aerodynamic coefficients.

5.6 Example 6: SR3C-X2 propfan — Time Domain Flutter

Description:

In this example, time domain flutter calculations are performed for the SR3C-X2 propfan blade (Ref. 4). For this flutter calculation, both in-phase and out-of-phase motions are considered. Two blade passages are included in the calculations. Version 4 of the FPCAS3D code is used. The steady flow conditions and the grid used are the same as in example 4, except that the number of Newton sub-iterations used in the steady run is 5. As before, a non-dimensional time step of 0.02 is used with 2 Newton sub-iterations at each time step. The two blades are given a small initial velocity in each mode. The velocity given to the blades is equal in magnitude and opposite in direction (sign). The calculations are continued until a non-dimensional time of 10.0 (total of 500 time steps).

paral.f:

```
PARAMETER ( IMX=56, JMX=11, KMX=24 )
```

para2.f:

```
PARAMETER ( NXPM=21, NRPM=21, NNODM=500 )
```

para3.f:

```
PARAMETER ( NPS=2 )
```

fpcas3d.input:

```
TITLE
SR3CX2 BLADE; TIME DOMAIN FLUTTER RUN.
IEXTR      INUM      INI
0           2         1
MINF
0.7
ADV         BET3Q      SOMGA
3.55        61.2       1.0
NTMX        DTAU       NBS
500         0.02       2
NSTDY       FACTOR
2           0.01
RHUB0
0.325
P0          A0
13.102      13560.0
NMODE
3
( OM(IM), IM = 1, NMODE )
221.082     402.1287   698.2002
( GM(IM), IM = 1, NMODE )
2.408413E-05 2.444044E-05 1.445758E-05
( VEL5(NBLADE), NBLADE = 1, NBS )
1.0         -1.0
IAIRFL
0
( TMAX(J), J = 1, 15 )
0.085  0.073  0.055  0.049  0.040
0.037  0.033  0.030  0.027  0.024
0.021  0.0205 0.02   0.02   0.02
( CHD16(J), J = 1, 15 )
0.      0.240  0.340  0.390  0.435
0.470  0.492  0.500  0.490  0.465
0.430  0.395  0.295  0.155  0.01
```

fpcas3d.blade.input:

same as in example 4

fpcas3d.mode.input:

same as in example 4

fpcas3d.output:

```
SR3CX2 BLADE; TIME DOMAIN FLUTTER RUN
```

```
IEXTR = 0
INUM = 2
```

```

INI = 1
MINF = 0.7000
ADV = 3.5500
BET3Q = 61.2000
NTMX = 500
DTAU = 0.0200
NBS = 2
NSTDY = 2
SOMGA = 1.0000
FACTOR = 0.10000E-01
RHUB0 = 0.32500E+00

P0, A0 :
0.1310E+02 0.1356E+05
NMODE = 3
OM(IM), IM = 1, NMODE :
0.2211E+03 0.4021E+03 0.6982E+03
GM(IM), IM = 1, NMODE :
0.2408E-04 0.2444E-04 0.1446E-04
VELS(NBLADE), NBLADE = 1, NBS :
0.1000E+01 -0.1000E+01
TMAX(J), J = 1, 15 :
0.8500E-01 0.7300E-01 0.5500E-01 0.4900E-01 0.4000E-01
0.3700E-01 0.3300E-01 0.3000E-01 0.2700E-01 0.2400E-01
0.2100E-01 0.2050E-01 0.2000E-01 0.2000E-01 0.2000E-01
CHD16(J), J = 1, 15 :
0.0000E+00 0.2400E+00 0.3400E+00 0.3900E+00 0.4350E+00
0.4700E+00 0.4920E+00 0.5000E+00 0.4900E+00 0.4650E+00
0.4300E+00 0.3950E+00 0.2950E+00 0.1550E+00 0.1000E-01
FROM NAST1, IN DEGREES, DBET=
0.00000E+00

FROM NAST1, RTIP=
0.12458E+02

NT= 0 UNDEFORMED BLADE
IMAX = 47
JMAX = 11
KMAX = 22
ILE = 20
ITE = 34
JTIP = 15

FROM GRID:
XXLE, YYLE, ZZLE =
-0.45218E-01 0.37500E+00 -0.66245E-01
XXTE, YYTE, ZZTE =
0.10285E+00 0.37500E+00 0.15224E+00
BETA =
0.61091E+02

NT= 1 NITER= 1 NBLOCK= 1
TSRES= 0.3898E-03 SDPHI= 0.7613E-05 SDPHDT= 0.1870E-03
NT= 1 NITER= 1 NBLOCK= 2
TSRES= 0.3900E-03 SDPHI= 0.7462E-05 SDPHDT= 0.1870E-03
NT= 1 NITER= 2 NBLOCK= 1
TSRES= 0.3898E-03 SDPHI= 0.2370E-05 SDPHDT= 0.4461E-03
NT= 1 NITER= 2 NBLOCK= 2
TSRES= 0.3899E-03 SDPHI= 0.2373E-05 SDPHDT= 0.4359E-03
NT= 1 NITER= 3 NBLOCK= 1
TSRES= 0.3898E-03 SDPHI= 0.1759E-05 SDPHDT= 0.3856E-03

```

NT= 1 NITER= 3 NBLOCK= 2
TSRES= 0.3899E-03 SDPHI= 0.1753E-05 SDPHDT= 0.3783E-03

216 lines deleted for brevity

NT= 500 NITER= 1 NBLOCK= 1
TSRES= 0.3929E-03 SDPHI= 0.2650E-05 SDPHDT= 0.4161E-03
NT= 500 NITER= 1 NBLOCK= 2
TSRES= 0.3869E-03 SDPHI= 0.2850E-05 SDPHDT= 0.6217E-03
NT= 500 NITER= 2 NBLOCK= 1
TSRES= 0.3935E-03 SDPHI= 0.1699E-05 SDPHDT= 0.3676E-03
NT= 500 NITER= 2 NBLOCK= 2
TSRES= 0.3863E-03 SDPHI= 0.1906E-05 SDPHDT= 0.6116E-03
NT= 500 NITER= 3 NBLOCK= 1
TSRES= 0.3933E-03 SDPHI= 0.2265E-05 SDPHDT= 0.4328E-03
NT= 500 NITER= 3 NBLOCK= 2
TSRES= 0.3865E-03 SDPHI= 0.2520E-05 SDPHDT= 0.6669E-03

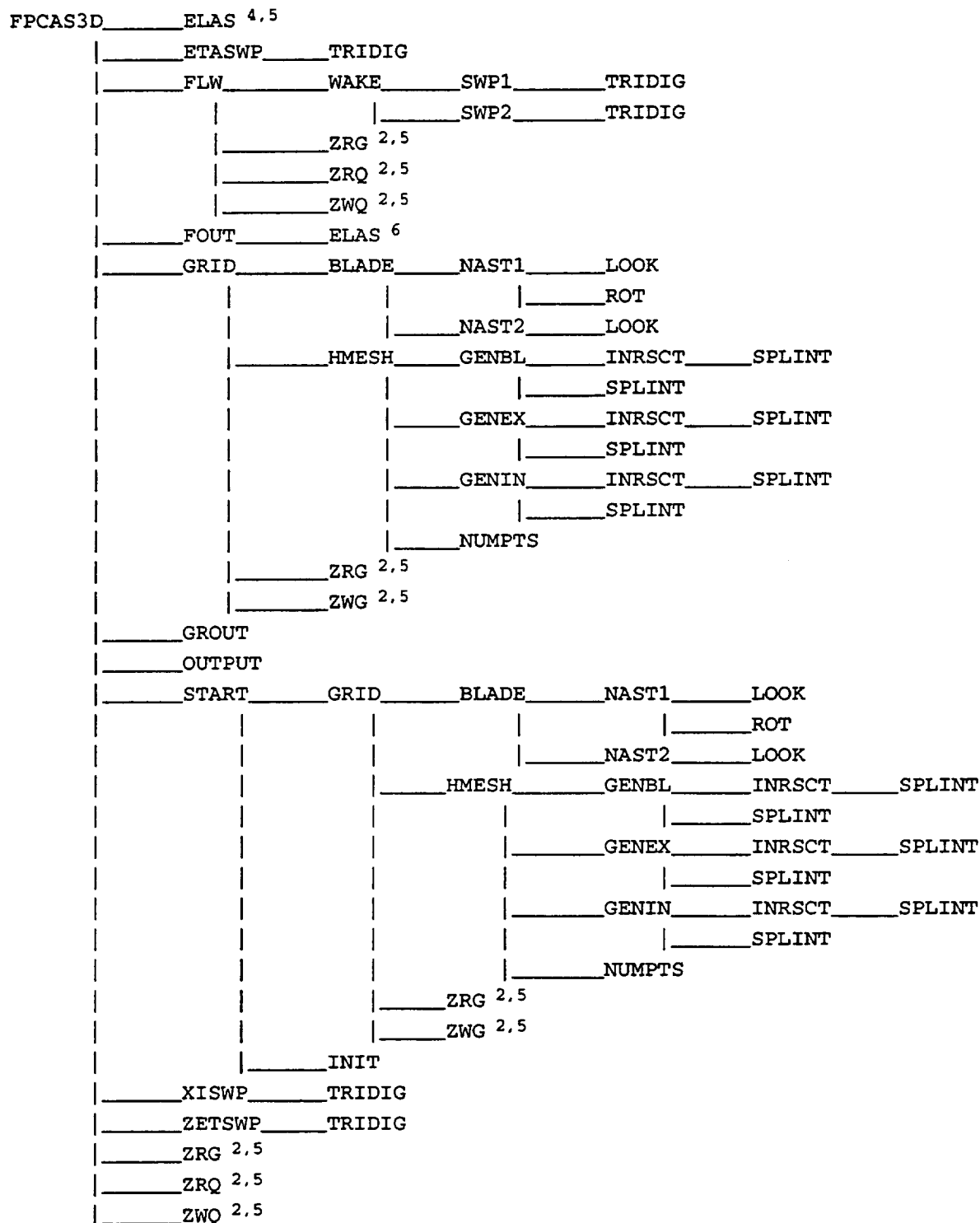
CP-STAR=
-0.77907E+00

additional output files:

fort.53-57 time history of residuals
fort.61-62 time history of blade motion (modal displacements)
fort.71-72 time history of generalized forces on blades

6. PROGRAM CALLING TREE

The following is the static calling tree for the FPCAS3D code. Superscripts indicate version numbers of FPCAS3D in which the routines appear exclusively.



7. REFERENCES

1. Ku, C.-C. "Three Dimensional Full Potential Method for the Aeroelastic Analysis of Propfans" Ph.D. thesis, Purdue University, West Lafayette, Indiana, Nov. 1989.
2. Ku, C.-C. and Williams, M. H. "Three-Dimensional Full-Potential Method for the Aeroelastic Modeling of Propfans" AIAA Paper 90-1120, Apr. 1990.
3. Bakhle, M. A. and Reddy, T. S. R. "Unsteady Aerodynamics and Flutter of Propfans Using a Three-Dimensional Full-Potential Solver" AIAA Paper 93-1633, Apr. 1993.
4. Bakhle, M. A., Keith, T. G., Jr., and Williams, M. H. "Unsteady Aerodynamics and Flutter Based on the Potential Equation" AIAA Paper 93-2086, June 1993.
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13. ABSTRACT (Maximum 200 words) The FPCAS3D computer code has been developed for aeroelastic stability analysis of bladed disks such as those in fans, compressors, turbines, propellers, or propfans. The aerodynamic analysis used in this code is based on the unsteady three-dimensional full potential equation which is solved for a blade row. The structural analysis is based on a finite-element model for each blade. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis are not given in this report. This guide can be used to assist in the preparation of the input data required by the FPCAS3D code. A complete description of the input data is provided in this report. In addition, six examples, including inputs and outputs, are provided.				
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